The Reaction of Nitrogen With 2195 Aluminum-Lithium Alloy: Continued

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In the *1994 MSFC Research and Technology Report*, attention was called to a detrimental reaction of nitrogen with 2195 aluminum-lithium alloy occurring at temperatures as low as 350 °C.

Optical hot-stage microscopy carried out at MSFC by Dr. J.E. Talia of Wichita State University and his student C.A. Widener, showed bubbling at grain boundaries during melting clearly indicating a gas reaction. Thermocouple measurements during the hot-stage microscopy showed this reaction to be exothermic, like the reaction of the 1994 differential thermal analysis (DTA) curves. The bubbling reaction, also like the DTA reaction, began in the neighborhood of 350 °C.

Followup gas chromatograph studies of 2195 alloy heated in an alumina tube to 620 °C for 15 min with pure nitrogen and with air revealed that for a mole of nitrogen lost approximately a mole of hydrogen appeared. Because hydrogen is so easily lost, for example by absorption in container walls, appreciably more hydrogen may have been generated than the measured quantity.

The appearance of hydrogen and the absence of grain boundary bubbling in lithium-lacking 2219 aluminum alloy points to a reaction of nitrogen with a lithium-hydrogen compound or compounds causing a release of hydrogen. The details of the reaction remain to be worked out although hydrogen containing lithium compounds in aluminum-lithium alloys are well known. Exposure to air containing a bit of moisture easily contaminates lithium containing alloys. Hot-stage microscopy shows that vacuum degassing can eliminate the reacting compounds, but this is not practical for shop practice. In practice a thin layer, for instance a quarter of a millimeter, of surface is machined off prior to welding to avoid the worst of the problem.

D. Huang, a student of Dr. J.C. McClure at the University of Texas at El Paso, measured the effect of contamination levels of nitrogen, oxygen, and hydrogen in the argon plasma gas and helium shield gas of a variable polarity plasma arc (VPPA) welding torch on a sample of 2195 aluminum. He ran gas compositions over a range from 10 to 500 p/m and from gas flow rate and weld speed computed a contamination volume per length of weld. He measured pore areas (up to 1.1 percent of the weld area; up to 0.16 mm^2) as a function of contamination volume per weld length.

All three gases caused porosity, but nitrogen always caused the highest porosity levels. A gray to black surface film of 1 to 2 µm irregularly shaped metallic aluminum particles sometimes appeared on the metal surface. The metallic particles might have been gas-driven ejecta from grain boundaries or surface pores.

A somewhat different film was observed by Talia in the vicinity of a crack: a loosely attached dark film of 10 µm diameter spherical particles. These spheres seemed to have a metallic interior with a sometimes cracked nonmetallic shell; EDAX analysis showed Al, Mg, Cu, O, N. (Li is not detectable by this technique.) The roundness of the particles suggests solidification while suspended in a gas.

It is noteworthy that hydrogen contamination appears to cause substantially less porosity in 2195 alloy than in 2219. This may be due to the formation of hydrogen compounds in the lithium-containing alloy.

The backside of a weld can easily exceed 350 °C below a weld pool of appreciable depth during a partial penetration cover pass. Hence even the backside of a partial penetration cover pass in an aluminum-lithium alloy should generally be shielded.

Talia, G.E. and Widener, C.A.: "High Temperature Analysis of Aluminum-Lithium 2195 Alloy to Aid in the Design of Improved Welding Techniques." Report: NASA/ASEE Summer Faculty Fellowship Program, MSFC, Summer 1996.

Huang, D.; McClure, J.C.; and Nunes, A.C.: "Gas Contamination During Plasma Welds in Aluminum Lithium Alloy 2195." Submitted to *Welding Journal*, 1996.

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Biographical Sketch: Dr. Arthur Nunes is an aerospace engineer with NASA's Materials and Processes Laboratory at Marshall, specializing in the theory of welding processes, basic engineering science, and materials science. He holds a Ph.D. in materials engineering from the University of California at Berkeley.